other members of the family Ectatommidæ. The mistakes he would then discover would be, I realize, still more embarrassing than those he has detected at so much longer range, but the discussion of them might have a correspondingly greater scientific value. And yet it may be that even in this I am still begging the question or asking an unfair advantage, for increasing knowledge often sets cruel limits in the free fields of literary sport.

O. F. COOK.

VICTORIA, TEXAS,
December 16, 1905.

SPECIAL ARTICLES.

A NEW THEORY OF SEX-PRODUCTION.[1]

THE last volume of the *Proceedings* of the German Zoological Society contains an interesting address by Professor Richard Hertwig in which is developed a new theory of sex-production based on his long-continued experiments on protozoa and applied to the interpretation of the results of new experiments by himself on amphibia and those of his pupils Issakowitsch and von Malsen on daphnids (*Simocephalus*) and on *Dinophilus*. Professor Hertwig's conclusions demand especial attention, since they are on the whole antagonistic to the view, which has been widely accepted in recent years, that sex is already determined in the fertilized egg, though he does not deny that such early determination may exist in some cases.

The new experimental results brought forward are as follows: The work of Issakowitsch (since published in full in the *Biologisches Centralblatt*) proves that in *Simocephalus* sex-production shows a definite reaction to temperature changes. At 24° C. a parthenogenetic production of females, with only the occasional appearance of a male, continues until the culture dies out; while a reduction to 16° quickly leads, and reduction to 8° immediately leads, to the appearance of males and later (sometimes immediately) to the production of winter eggs. Issakowitsch also shows that a similar effect may be produced by starvation without change of temperature, and hence he concludes (like Nussbaum in the case of rotifers) that the change of temperature probably acts indirectly through its effect on nutrition. Von Malsen's work on *Dinophilus* shows that in a culture maintained for months at 10°–12° C. male and female eggs are produced in a ratio of 1:3, while at 25° the ratio rises to 1:1.75, and sometimes reaches 1:1. Both these cases seem free from the objection that applies to so many of the earlier experiments on sex-modification that the statistical results may be vitiated by different rates of mortality in larvæ of different sexes. Unfortunately the same can not be said of Professor Hertwig's own experiments on frogs, ingenious and interesting as they are. Experiments with changes of temperature gave no really satisfactory result, though Hertwig seems inclined to believe that higher temperatures favor the production of females. On the other hand, either over-ripeness or under-ripeness of the eggs (a condition obtained by artificially delaying or hastening fertilization) led in every case to a large excess of males. Like those of earlier observers, these results are not very convincing, owing to the high mortality of the larvæ, which must be reared to the time of metamorphosis before the sex can certainly be determined. The most satisfactory results appear to have been obtained from a culture of over-ripe eggs in which 20 per cent. to 30 per cent. of the fertilized eggs were reared to this period, the result being 317 males to 13 females; and in one case of under-ripe eggs 40 larvæ that were successfully reared were all males. These results can hardly be ascribed to accident; but the dubious character of the statistical data obtained by rearing tadpoles and other larvæ through long periods of time has been so clearly shown by the experience of many other observers that the true interpretation of the facts in this case seems by no means clear.

Hertwig's general theory of sex-production was primarily suggested by his own earlier experiments on the relation between nucleus and protoplasm in the protozoa. These experiments led him to the conclusion that the

[1] R. Hertwig, 'Ueber das Problem der sexuellen Differenzierung,' in *Verhandlungen der Deutschen Zoologischen Gesellschaft*, 1905.

ratio between the nuclear and the protoplasmic mass (the 'Kernplasmarelation,' expressed by the formula k/p) tends towards a normal value that is in the long run constant for the species, though it undergoes cyclical changes both in the individual cell and in successive generations of cells. In ordinary or 'functional' growth the value of k/p undergoes a temporary decrease, owing to the more rapid growth of the protoplasm, but this induces a subsequent more rapid 'divisional' growth of the nucleus which raises the value of k/p to a point above the normal, and finally leads to cell-division by which the normal ratio is again approximately restored. Long-continued 'autogenous' (*i. e.*, vegetative or asexual) reproduction causes, however, a gradual permanent increase in the value of k/p (*i. e.*, a nuclear hypertrophy) and this necessitates a reorganization by conjugation through which the normal condition is restored. The value of k/p may also be experimentally altered by conditions of food, temperature and the like; and here, according to Hertwig's view, lies the possibility of affecting the sexual relations by external conditions.

Professor Hertwig's application of this conception to sex-production in the metazoa is, we think, open to serious criticism. His central assumption is that the 'Kernplasmarelation' differs in the two sexes, having a higher value in the male (*i. e.*, the nuclear mass is assumed to be relatively greater in that sex), and any influence that tends to increase this value, whether in the gametes, in the zygote, or in the developing embryo, favors or determines the production of the male condition, and *vice versa*. Since the egg contributes to the germ the entire mass of protoplasm and half the nucleus, while the spermatozoon contributes only half the nucleus, 'the egg naturally takes the lion's share' in the determination of the 'Kernplasmarelation' and hence in the determination of sex. In case of the frog, over-ripe and under-ripe eggs tend alike to produce males, because in the former (long retained in the oviduct) the nuclear substance has increased at the expense of the protoplasm, while in the latter the protoplasm has not yet completed its growth—either case giving a relatively high value to k/p. In view of the fact that the nucleus breaks down and the first polar spindle is formed at the time the egg leaves the ovary, this explanation does not seem very convincing, at least in the case of over-ripe eggs. As applied to the cases of *Simocephalus* and *Dinophilus* the argument becomes too involved for detailed review here, since the two cases are diametrically opposed, a higher temperature favoring in the one a continued production of parthenogenetic females, and in the other the production of males; but here too Hertwig attempts to show that an explanation may be found in the assumption of alterations in the value of k/p directly or indirectly traceable to the effect of temperature.

It is somewhat surprising to find on how small a basis of actual fact the central assumption of the hypothesis rests. No new cytological evidence is brought forward, and the only facts given in direct support of the assumption are, first, that the value of k/p is enormously greater in the spermatozoon than in the egg, and secondly, that in all cases (such as *Dinophilus*) where male and female eggs are distinguishable before fertilization the former are smaller than the latter. It is difficult to see how the first of these facts bears on the problem, for the question is how the male or female value of k/p is produced in the *zygote*, which results from the fusion of one gamete from each sex whether it produces a male or a female. The second fact is assumed by Hertwig to mean that the male-producing eggs have a relatively high value of k/p, owing to a deficiency of protoplasm. 'Nach allem, was wir über Befruchtung wissen, müssen die Kerne dieser Kleineier (of *Dinophilus*) ebenso gross sein, wie die der Grosseier' (p. 196). But Korschelt's figures of *Dinophilus* show the nuclei of the small eggs very much smaller than those of the large ones, in the ovaries, in the new-laid eggs within the capsules, and in the early and late cleavage-stages, and there is no actual evidence, either in these eggs or in any of the other cases, that the value of k/p is greater in the males than in the females. On the contrary, in the only known cases of nuclear dif-

ference between the sexes (the protoplasmic mass being the same as far as can be observed) it is the female, not the male, that has the larger quantity of nuclear material. This fact has recently been demonstrated by the reviewer in a dozen different species of hemiptera, representing eight genera, and the structure of the spermatozoa shows that the same is undoubtedly true of many other species. The difference is here one of nuclear constitution and is irrespective of temporary changes of nuclear volume such as are common to all cells. But even here we can not regard the quantitative difference of the nuclei as being primarily responsible for the sexual differentiation, for in some of the species of the same group no perceptible difference in this respect exists between the sexes.

Without questioning the interest and value of Professor Hertwig's experimental results, it, therefore, seems to us that his theory of sex-production is without real foundation, and that, in the specific form that he has given it, it is untenable. E. B. WILSON.

ASTRONOMICAL NOTES.

THE FIGURE OF THE SUN.

Two articles by Professor Charles Lane Poor have recently appeared in *The Astrophysical Journal* dealing with a variation in the figure of the sun. This research comes with special interest at the present time, when so many writers are trying to trace relationships between various terrestrial phenomena and different forms of solar activity.

Among the remarkable photographic work done by Rutherfurd was a series of photographs of the sun. These are still of such unimpaired excellence that they permit admirable determinations of the sun's diameter. From a series of such plates extending over the years 1870–1872, measurements were made of the polar and equatorial radii, from a discussion of which it appears that the polar radius is sometimes greater and sometimes less than the equatorial radius. The individual determinations of this difference (polar radius —equatorial radius) vary between $+0.77''$ and $-0.72''$, and the means are as follows: for 1870, September 22, $+0.50'' \pm 0.10''$, for 1871, July 19, $-0.32'' \pm 0.16''$, and for 1872, July 2, $+0.22'' \pm 0.09''$. There is thus indicated a change in the relative values of the polar and equatorial diameters of the sun. This conclusion, if true, is of great importance, and it is not strange that Professor Poor desired to verify his results by reference to other and independent determinations of the form of the sun.

A large number of heliometer measurements of the diameter of the sun were available from a very thorough discussion, by Dr. Auwers, of the transits of Venus, in 1874 and 1882. Dr. Auwers reached the conclusion that the diameter of the sun at distance unity is 1,919.26″, and that the polar diameter slightly exceeds the equatorial diameter. This difference, however, was attributed by him to the personal equation on the part of the observers between measures of vertical and horizontal diameters. The observations as discussed by Auwers gave no indication of a variation in the relative values of the different diameters, but were rearranged in a form suitable for this discussion by Professor Poor.

Measurements were also made of a short series of photographs of the sun taken at Northfield by Dr. Wilson. Both the heliometer determinations and the Northfield photographs seem to confirm the results obtained from the Rutherfurd photographs. Professor Poor thus sums up his conclusions:

> The present investigation would seem to show, therefore, that the ratio between the polar and equatorial radii of the sun is variable, and that the period of this variability is the same as the sun-spot period. The sun appears to be a vibrating body whose equatorial diameter, on the average, slightly exceeds the polar diameter. At times, however, the polar diameter becomes equal to and even greater than the equatorial—the sun thus passing from an oblate to a prolate spheroid.

In a second paper Professor Poor extended his investigations to include the elaborate heliometer determinations of the sun's dimensions, carried on at Göttingen by Shur and Ambronn. These observations covered a full sun-spot period, from 1890–1902. Ambronn, who discussed the observations, gave his special attention to the mean diameter of the sun, so that again it became necessary to